CHARACTERIZING THE STRUCTURE OF COFFEE AGROFORESTRY SYSTEMS IN COSTA RICA

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Recherche de compromis entre productions et services écosystémiques fournis par les systèmes agroforestiers tropicaux

Guerric le Maire [1,2], Florian RANÇON [1,3], Fabien CHARBONNIER [1,4,5], Olivier ROUPSARD [1,5]

guerric.le_maire@cirad.fr

(1) Cirad, UMR Eco&Sols, Montpellier, France, (2) Cirad, UMR TETIS, Montpellier, France, (3) SupAgro, UMR Eco&Sols, Montpellier
(4) Université de Lorraine, UMR EEF, Nancy, (5) CATIE, Turrialba, Costa Rica

Introduction

- Agroforestry systems have a complex canopy structure difficult to scale up from field measurements only. The time course of coffee LAI has been characterized previously using MODIS and field measurements (Taugourdeau et al., 2014).
- Coffee understory is located under a tree stratum of variable density, size and phenology (e.g. leaf area index dynamics, different species).
- This shade tree stratum plays an important role in the light environment and microclimate of the understory, and ultimately impacts the production of coffee fruit.
- Pleiades very high spatial resolution satellites images allow to characterize these systems in terms of tree coverage and leaf area indices at appropriate spatial scale (from tree to plot), and at different dates

Available images:

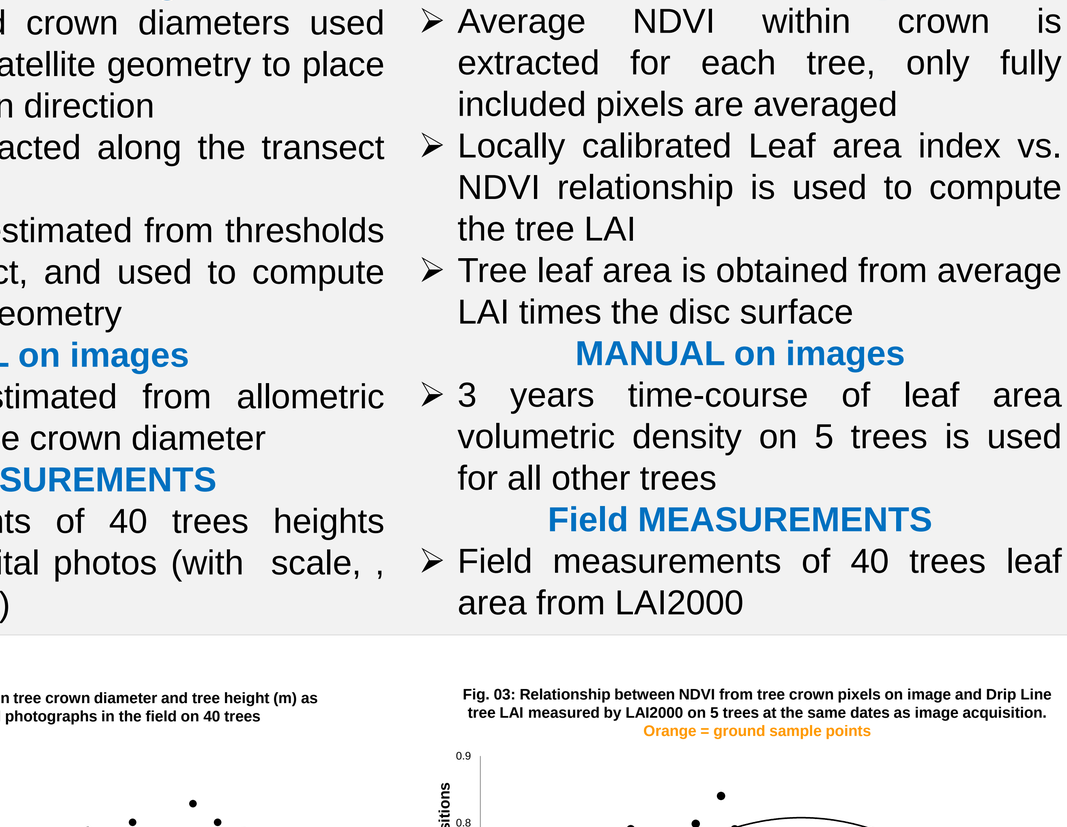
Date of acquisition	Provider	Bands	Sun elevation	Sun azimuth	Satellite elevation	Satellite azimuth
2001-12-01	Google Earth	R/G/B 0.5m	NA	NA	NA	NA
2005-03-07	Aerial photography	R/G/B 1.5m	NA	NA	NA	NA
2008-02-16	WORLDVIEW	PAN 0.5m	53.2	135.6	81.3	289.9
2010-03-29	WORLDVIEW 2	PAN 0.5m B/G/R/NIR 2m	66.4	104.0	70.8	121.5
2012-12-04	PLEIADES (1A)	PAN 0.5m R/G/B/NIR 2m	53.4	151.7	69.6	180.0
2013-03-25	PLEIADES (1A)	PAN 0.5m R/G/B/NIR 2m	65.9	107.4	79.6	180.0
2013-12-23	PLEIADES (1B)	PAN 0.5m R/G/B/NIR 2m	51.0	148.9	78.4	180.0

Site characteristics:

- Coffee based agroforestry system, Turrialba volcano, Costa Rica (9°56'19"N,83°43'46"W), 1km²
- Tropical humid climate
- *Coffea arabica* L. var Caturra
- *Erythrina poepigiana* O.F. Cook is used as shade tree: broadleaf deciduous tree that totally defoliates during February-March

Agroforestry system: Coffee trees plantation associated with Erythrina shade trees

General method



METHOD

Part I : tree detection and crown diameter

AUTOMATIC on images

- VHSR image treatment to create a 50 cm B&W image with enhanced contrast between tree crowns and background:

Pansharpening (OTB) ➔ Conversion to reflectance ➔ Georeferencing (QGIS) ➔ textures and vegetation indices combination (OTB)

- Crown discs detection with Hough circles method
- Smoothing/deconvolution filters for each tree size range
- Tree correspondance between images dates

MANUAL on images

- Photointerpretation: discs positionned on the image
- Tree correspondance between images dates

Field MEASUREMENTS

- Stratification by crown size and field measurement of 40 tree crown diameters from horizontal digital photos (with scale, 4 azimuths per tree)

Part II : tree height

AUTOMATIC on images

- Tree positions and crown diameters used together with sun/satellite geometry to place a transect along sun direction
- PAN profile is extracted along the transect for each tree
- Shadow length is estimated from thresholds of the PAN transect, and used to compute tree height, using geometry

MANUAL on images

- Tree height is estimated from allometric relationship with tree crown diameter

Field MEASUREMENTS

- Field measurements of 40 trees heights from horizontal digital photos (with scale, , 4 azimuths per tree)

Part III : tree leaf area

AUTOMATIC on images

- Average NDVI within crown is extracted for each tree, only fully included pixels are averaged
- Locally calibrated Leaf area index vs. NDVI relationship is used to compute the tree LAI
- Tree leaf area is obtained from average LAI times the disc surface

MANUAL on images

- 3 years time-course of leaf area volumetric density on 5 trees is used for all other trees

Field MEASUREMENTS

- Field measurements of 40 trees leaf area from LAI2000

RESULTS

Fig .01:Tree crown Automatic (A) /Manual (M) delimitation comparison by zone (Z)

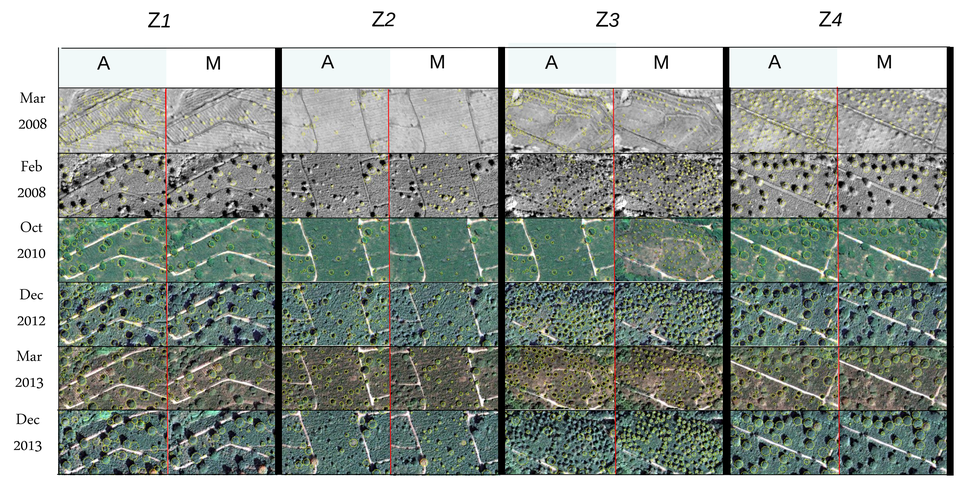


Fig. 02: Allometric relationship between tree crown diameter and tree height (m) as measured on horizontal digital photographs in the field on 40 trees

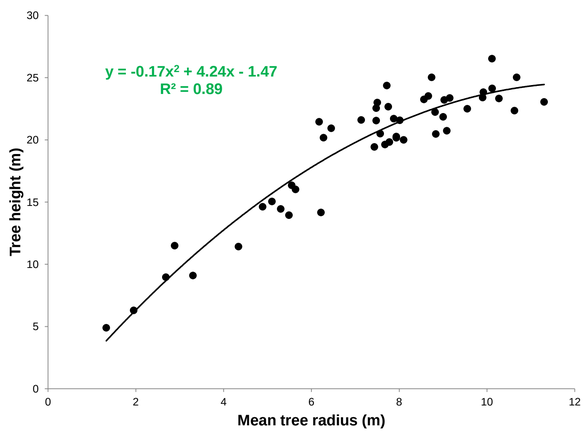
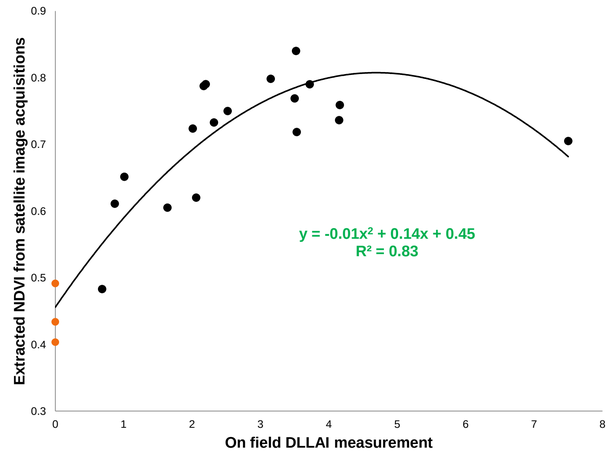


Fig. 03: Relationship between NDVI from tree crown pixels on image and Drip Line tree LAI measured by LAI2000 on 5 trees at the same dates as image acquisition.
Orange = ground sample points



Tab. 01: % of tree detections on images using the automatic method

% of undetected trees					
Zone	2008	2010	2012	Mars 2013	Déc 2013
1	2%	10%	13%	9%	14%
2	29%	14%	21%	14%	59%
3	10%	16%	22%	7%	33%
4	0%	18%	33%	15%	9%
% of false negative trees					
Zone	2008	2010	2012	Mars 2013	Déc 2013
1	30%	33%	48%	19%	35%
2	24%	32%	29%	7%	19%
3	73%	12%	12%	4%	24%
4	0%	0%	19%	39%	13%

Fig. 04: Automatic crown radius *vs* Manual crown radius on images

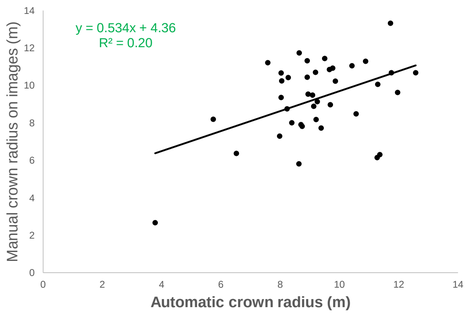


Fig. 05: Crown radius measured manually on images *vs* radius measured in the field with horizontal digital photographs

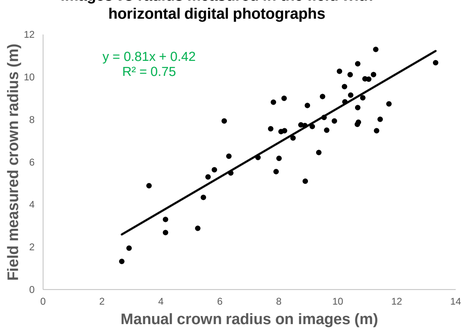


Fig. 06: Tree height estimated from shade projection *vs* measured in the field from digital photographs

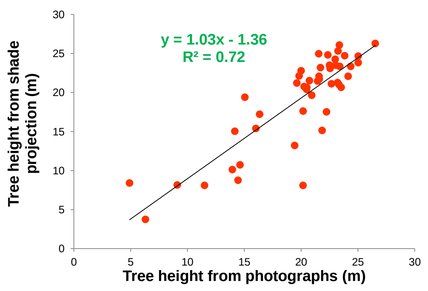
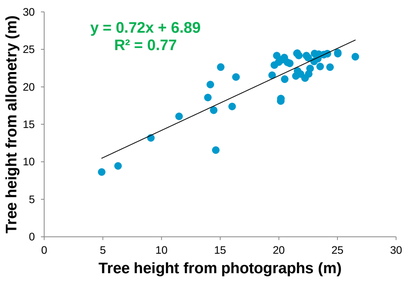


Fig. 07: Tree height estimated from allometric relationship with crown diameter on images *vs* tree height measured in the field



Evolution of structural properties with time

Fig. 08: Time course of fraction tree canopy coverage, from manual methods on images and for different zones

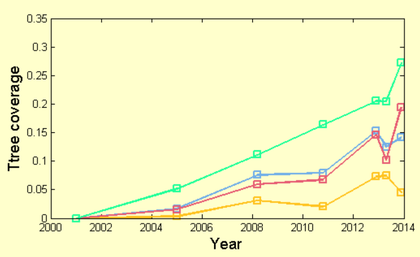


Fig. 09: Time course of tree height for different zones from manual and allometric methods on images

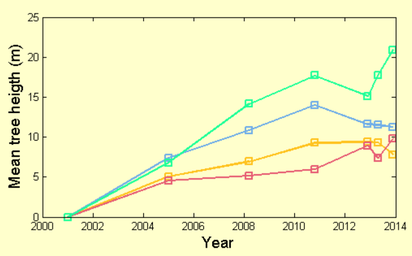
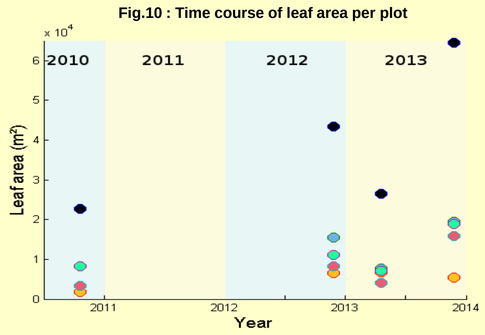


Fig.10 : Time course of leaf area per plot



Zone 1
Zone 2
Zone 3
Zone 4
All zones

Conclusions and perspectives

- Detection of shade trees is highly dependent on date of acquisition and phenological cycle: for instance mages acquired in February or March show less contrast between shade tree and coffee strata than images acquired in December
- Tree height estimations using a single allometric relationship between tree crown diameter and tree height is more precise than using the shadow-length method but requires a field calibration. Shadow-length method remains attractive when no field data are available
- The relationship between tree LAI and NDVI on image pixels is satisfactory to estimate shade tree leaf area for every image. On the contrary, leaf area volumetric density is less efficient because of inter-tree variability in phenology
- A consistent evolution of the shade tree characteristic was found confirming an increase of tree sizes since 2000. This evolution is different between zones
- Such time-series analysis of the evolution of the structure of shade trees can be input into a light interception and photosynthesis model (Charbonnier et al. 2013)

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***REFERENCES*:**

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- Taugourdeau, S., Le Maire, G., Avelino, J., Jones, J.R., Ramirez, L.G., Jara Quesada, M., Charbonnier, F., Gomez Delgado, F., Harmand, J.M., Rapidel , B., Vaast, P., Roupsard, O., 2014. Leaf Area Index as an indicator of Ecosystem Services and management practices in coffee agroforestry. Agric. Ecos. Envir. (in Press).